NUCLEAR SPINS AND MOMENTS OF RADIOACTIVE ISOTOPES INVESTIGATED BY AN ATOMIC BEAM METHOD

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INAUGURAL DISSERTATION

BY

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Nuclei in the vicinity of double closed shells are particularly interesting from a theoretical point of view, since there the single-particle model has been found to be a good approximation. The most complete experimental data are compiled for the lead region, near the "double magic" nucleus of Pb^{208}. During the last few years this region has been extensively investigated by various groups of nuclear spectroscopists.

The present works are contributions to the systematic study of the lead region, in that the ground-state spins, magnetic dipole and electric quadrupole moments of some radioactive bismuth and thallium isotopes have been measured with the atomic beam magnetic resonance technique. These experiments are complementary to those of the nuclear spectroscopists, since no definite statements about the ground state can be made from spectroscopic data only. In fact, with the small amounts in which the isotopes investigated here can be produced, the atomic beam method is at present the only applicable one for direct measurements of ground-state spins and moments.

The lead region is now also an object of an increasing theoretical study. In particular, some of the nuclei closest to Pb^{208} have been investigated thoroughly on the basis of the single-particle model, and the agreement with the experimental data has been found to be very good. For nuclei farther away from the closed shells, the calculations become much more complicated and the shell model description less valid. It is to be expected, however, that comparison between experimental data and theoretical calculations should be fruitful also in these cases, at least as far as the ground states and low-lying excited states are concerned.

The atomic beam apparatus and the measurements are described in the following papers, a summary of which will be given below.

I. I. Lindgren, Atomic beam resonance apparatus with six-pole magnets for radioactive isotopes, Nuclear Instruments *3*, 1 (1958).

II. C. M. Johansson and I. Lindgren, Spins of bismuth isotopes of masses 203, 204, 205, and 206, Nuclear Physics *9*, 44 (1958/59).

III. I. Lindgren and C. M. Johansson, Nuclear magnetic dipole and electric quadrupole moments of radioactive bismuth isotopes, Arkiv för Fysik *15*, 445 (1959).

IV. S. Axensten, C. M. Johansson, and I. Lindgren, Nuclear spins of the bismuth isotopes Bi^{199}, Bi^{200}, Bi^{201}, and Bi^{202}, Arkiv för Fysik *15*, 463 (1959).

V. I. Lindgren, C. M. Johansson, and S. Axensten, Nuclear ground-state spins of Tl^{198} and Tl^{201}, Physical Review Letters *1*, 473 (1958).

In *Paper I* are described the main features of the six-pole focusing atomic beam apparatus and the principles of operation. The underlying theory for spin and moment determinations is also briefly reviewed. The transmission (effective solid angle) of the apparatus is calculated to be about $3 \cdot 10^{-4}$ steradians in a typical case, which is one order of magnitude larger than can be obtained in an atomic beam apparatus of the conventional type.

Paper II is a report of spin measurements of four radioactive bismuth isotopes. The experimental procedure is briefly described, and the spin values obtained are compared with theoretical values.

In *Paper III* are reported the measurements of the magnetic dipole and electric quadrupole moments of the bismuth isotopes Bi^{203}, Bi^{204}, and Bi^{206}. The magnetic moments are calculated from the magnetic interaction constants by means of the known values of Bi^{209} and the Fermi-Segré formula, neglecting the hyperfine structure anomaly. In the calculation of the quadrupole moments from the quadrupole coupling constants, the average value $\langle r^{-3} \rangle$ for the electrons is taken from the magnetic hyperfine structure of Bi^{209}. The atomic state of intermediate coupling is determined from the optical energy levels and from the known g_J-value of the ground state. The experimental values of the moments are discussed in relation to simple calculations based on the nuclear shell model. All the magnetic moments are found to be in good agreement with those obtained from the "modified" single-particle model. Of the quadrupole moments, on the contrary, only that of Bi^{206} is in agreement with the

single-particle value, while those of Bi^{204} and Bi^{203} are considerably larger. This discrepancy is probably caused by collective motions in the nuclei.

In *Paper IV* the spin measurements of four short-lived bismuth isotopes are reported, namely 1.6 hour Bi^{202}, 1.85 hour Bi^{201}, 35 minute Bi^{200}, and 25 minute Bi^{199}. For the study of isotopes with half-lives of the order of half an hour the oven arrangement has been modified, so that the main oven can be rapidly locked into position without disturbing the high vacuum. Identification of the isotopes is particularly important in this case and has been discussed separately. A summary is given in this paper of all measured spins of neutron-deficient bismuth isotopes and of the most probable nuclear configurations. All spin values are consistent with the shell model, but some irregularities in the coupling between the odd particles and in the neutron filling order must be assumed in order to explain the spins of Bi^{202} and Bi^{200}. No indications of an isomeric state in Bi^{201} have been found.

In *Paper V* the measurements of the ground-state spins of two thallium isotopes are reported. The spin of Tl^{198} is particularly interesting, since it confirms the assumed decay schemes of Pb^{198} and $Tl^{198\,m}$. The magnetic moment of the ground state is found to be extremely small. This might be the reason that the spin of Tl^{198} has not been found before.

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